A Partnership for Modeling the Marine Environment of Puget Sound, Washington

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LONG-TERM GOALS

Puget Sound, Washington, is both the largest fjord in the lower forty-eight states and closest to the substantial urban centers of Seattle, Tacoma, Everett and surrounding communities. The sound has seasonally high annual phytoplankton standing stock and primary production, and they support several economically valuable fisheries. Our long-term goals are to develop quantitative understanding of the Sound's circulation and marine ecosystem, and of the sensitivity of the physical and the biological system to natural and human perturbations; and to develop models of Puget Sound that can aid agencies with responsibilities for environmental management in making informed decisions and serve as marine science education tools.

OBJECTIVES

Our partnership will develop, maintain and operate a suite of flexibly linked simulation models of Puget Sound's circulation and ecosystem, a data management system for archiving and exchanging

oceanographic data and model results that are accessible to all members of the partnership as well as to the regional and oceanographic community, and an effective delivery interface for the model results and observational data for research, education and policy formulation. Our partnership will conduct scientific research aimed at developing fundamental understanding of the Sound's working, as well as addressing practical questions raised by the regional community concerning management of the Sound and its resources. Our partnership will function as an estuarine research node within the NOPP Ocean Information Commons.

APPROACH

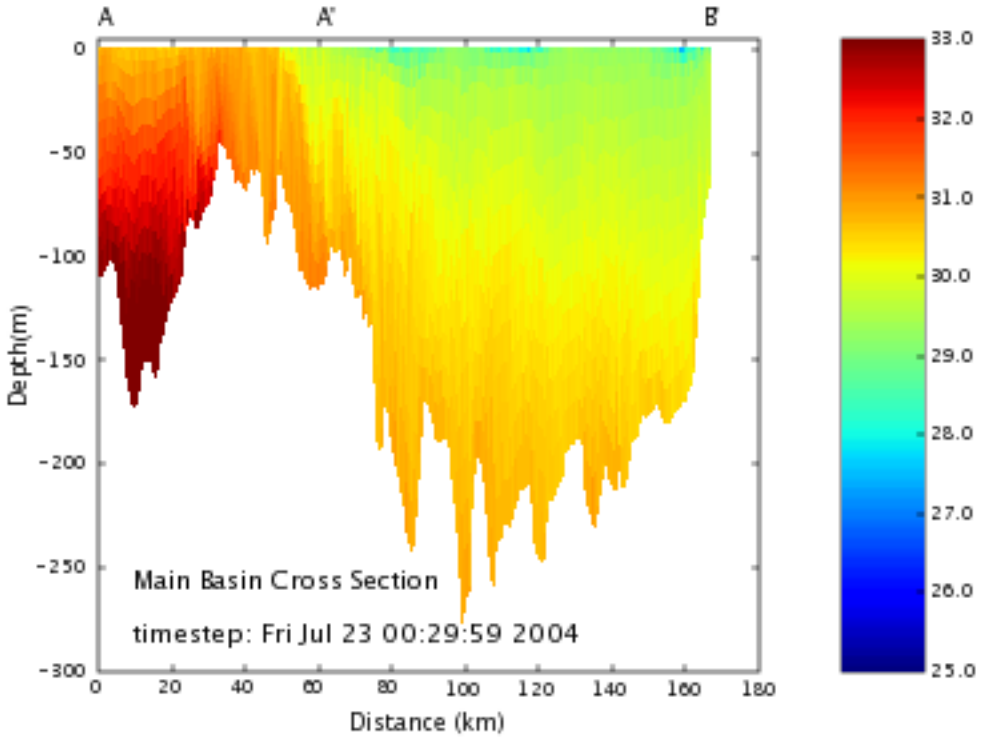
The partnership consists of five separate organizations: University of Washington (UW, School of Oceanography and College of Education), Department of Natural Resources and Parks, King County, Washington (KC-DNR), Washington State Department of Ecology (WA-DOE), Puget Sound Naval Shipyard (PSNS)/SPAWAR, and Ocean Inquiry Project (OIP). It is administered from School of Oceanography, UW. Collectively we are operating or developing four dynamically based, predictive models of the Sound's aquatic environment, each with a different spatial coverage (and a fifth module for biogeochemistry), and our goal is to integrate these modeling efforts into a coordinated whole. Our tasks are divided as follows:

- Project coordination: Mitsuhiro Kawase (UW)
- Model operation and development:
    - Puget Sound Circulation Model: Kawase, Bruce Nairn (KC-DNR)
    - Sinclair-Dyes Inlet Model: Robert Johnston (SPAWAR), P.F. Wang (SPAWAR)
    - South Puget Sound Model: Jan Newton (WA-DOE), Skip Albertson (WA-DOE)
    - Duwamish Estuary/Elliott Bay Model: Randy Shuman (KC-DNR)
    - Aquatic Biogeochemistry Model (ABC): Allan Devol (UW), Nairn, Newton
- Data management and infrastructure: Miles Logsdon (UW), Mark Warner (UW)
- Education and visualization: William Winn (UW), Fritz Stahr (OIP)

WORK COMPLETED

During the FY 2005 reporting period, the University of Washington has made progress on the development and implementation of the partnership's data infrastructure. The system is a metadatabase given the name Indigo implemented an OpenDAP server to start dissemination of results from POM daily hindcasts in a numerical format.

We have also developed a system for on-demand, on-the-fly generation of section and plane plots and animations, to replace the current pre-generated animations. An example salinity section from the Strait of Juan de Fuca through the axis of the Main Basin is shown below.



The Aquatic BiogeoChemistry (ABC) Model has been implemented for the entire Puget Sound. A sediment biogeochemistry model has been developed by post-doc Steve Colbert, and has been applied to Dabob Bay.

A post-doc has been hired (Dmitri Leonov, Ph.D. Florida State University July 2005) to work on a coast-sound linkage model. The data management system can now serve metadata listing from the website. It has been populated with POM model results metadata and hydrography metadata from PRISM cruises. Listings will be made available to the public soon.

The partnership is at a stage to start soliciting data from agencies and scientific institutions in the region. Our data system will service Hood Canal Dissolved Oxygen Program (HCDOP). We have started discussion with Northwest Association of Networked Ocean Observing Systems (NANOOS). The partnership may also be in a position to service data management needs of Puget Sound Ambient Monitoring Program (PSAMP) and will initiate discussions with them.

The education group's main work during the year has focused on further development of Virtual Puget Sound (VPS), determining how it can best be used in courses, and analyzing data obtained during from the study of VPS's effectiveness with younger students.

Our development work has been mainly directed towards allowing users of VPS to easily import and run files containing data from different days, in different formats, and with different data fields. We are also developing the capability for users to construct and save "profiles" that reflect their preferences and interests in how they view and use the data, giving users control over aspects of the software that have so far been "hard-wired" into the code.

We have completed two studies of how expert oceanographers, expert science teachers and science teachers in training conceive of using VPS in their classes. We have developed a number of lesson plans, for different disciplines within science and for students at different levels, which will soon be posted on the PSMEM website for teachers to download and use alongside VPS. VPS will be used in at least one oceanography class at the University of Washington this year. We are working with the instructor to plan curriculum and activities for the class, and will be able to gather further data on how VPS can be used.

The group has worked in collaboration with psychologists, special educators and brain imagers to analyze and interpret data obtained from a recent study of the effects of VPS on normal readers and dyslexic children's ability to solve problems. This work is leading to insights into how students in upper elementary grades interact with dynamic simulations of complex natural phenomena and to the cognitive and neurological changes that result from using VPS.

RESULTS

As part of our support for the Hood Canal Dissolved Oxygen Program, we did a study of the model circulation in Hood Canal. We found a three-layer circulation consisting of a thin, outgoing surface layer, a mid-depth inflow layer, and a bottom layer moving towards the exit. The outgoing surface layer corresponds to a layer of relatively fresh water deriving from river inflow on top of a shallow pycnocline. The circulation is sensitive to the local wind, and patterns of wind-driven upwelling similar to the observed distribution of fish kills due to upwelling of subsurface hypoxic waters can be seen in the model. This result was reported at the Puget Sound – Georgia Basin Conference in Seattle WA in April 2005.

The Aquatic BiogeoChemistry – Sediment (ABC-Sed) model was developed primarily based on the Soetart et al. (1996) time dependent pore water model [x]. However, several changes have been made. First, to accommodate the ABC water column model, two additional solutes were added to the model: DOM and PO4. In addition, the C:N:P ratio of labile and refractory organic carbon were independently defined based on the ABC-water column output. Second, the model had to be adjusted for an estuarine/ fjord environment. Diffusion coefficients must be sensitive to changes in temperature and salinity. And, ammoniafication and denitrification was treated as separate processes, unlike some models. Third, characterization of irrigation and bioturbation was based on data collected in Puget Sound instead of using global averages.

Version 3.0 of VPS is now relatively stable and will be installed in the Spatial Analysis Lab. in the Oceanography Department in the next few weeks.

Eighteen lesson plans for instructors wishing to use VPS in classes have been developed.

Three papers were presented during the year at international education research conferences that describe our recent work.

IMPACT/APPLICATIONS

National Security

An improved modeling capability of the circulation and marine ecosystem of Puget Sound will help local and regional government devise procedures to deal with, for instance, chemical/biological attacks involving harmful agents that may be/need be flushed down into our marine waters, and with terrorism aimed at military and industrial installations that may result in environmental contamination.

Economic Development

Predictive modeling of Puget Sound's circulation and marine ecosystem will have positive impacts on many economic activities taking place in the Sound. For instance, forecasting of harmful algal blooms (HABs) and better understanding of hypoxia-induced fish kills in the Sound will help commercial fisheries better deal with this threat to their livelihood. Detailed knowledge of currents and hydrography will help diving operators with their underwater work. Understanding longer term variability in water quality leading to marine ecosystems change will help managers of fisheries resources make decisions.

Quality of Life

The Puget Sound region has always enjoyed a quality of life directly related to the quality of our environment. Our models provide tools for evaluating the impact of regional scale actions on the marine environment by predicting response of the latter to potential stressors. Oceanographic knowledge also has direct uses and benefits for those who work and live at sea. For instance, knowledge of currents will help Coast Guard and regional law-enforcement agencies with search and rescue operations and contaminant spill containment.

Science Education and Communication

With the aid of suitable visualizations, support material, and curriculum modules, the model results will be a valuable tool for learning about Puget Sound's marine environment that can be used in classroom settings as well as by the public at large in museums and through the web.

TRANSITIONS

Quality of Life

We are providing modeling resources in terms of expertise and computational hardware to Hood Canal Dissolved Oxygen Project (HCDOP). This collaborative project has been developed in response to concerns of residents of communities around the canal about recurrent fish kills in Southern Hood Canal in recent years, which are believed to be due to persistent hypoxia in the marine waters of this region. HCDOP has received congressional funding as well as funding from National Fish and Wildlife Foundation for FY 05 and 06 for a comprehensive study of hypoxia in Hood Canal encompassing observations and modeling of circulation and biogeochemistry of the marine waters and terrestrial inputs of fresh water, nutrients and organic matter. The project's goals are to sort out anthropogenic changes in the oxygen level, if any, from natural variabilities, and to assess the

effectiveness of proposed remedial measures. We have provided initial estimates of oxygen consumption rates using a simple box model of Puget Sound circulation ([2, 3]).

RELATED PROJECTS

The partnership continues a strong cooperative relationship with Puget Sound Regional Synthesis Model (PRISM, www.prism.washington.edu), a University of Washington project to develop and consolidate University-wide expertise in natural and human environment of the Puget Sound region.

The partnership's work compliments work being conducted under PSNS & IMF Project ENVVEST [4] to conduct modeling studies of the Sinclair and Dyes Inlet Watershed to assess the impact of CSO discharges on water quality of the Inlets [5] and support the development of TMDLs for the watershed [6, 7].

As described above, partnership scientists will play an active role in the Hood Canal Dissolved Oxygen Project.

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